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THE ELECTROCARDIOGRAM OF ANGINAL ATTACKS INDUCED BY EXERCISE

Clinicians are agreed that the history of the patient is the most valuable diagnostic criterion of angina pectoris. In doubtful cases it is desired to have objective evidence of the ischemia of the myocardium, and this evidence may often be given by the electrocardiogram recorded during the anginal attack.

While the pain of angina pectoris was suspected as being due to coronary artery insufficiency by Edward Jenner (1749-1823), it was not until the clear exposition of Resnik and Keefer (1928) that anginal pain was definitely related to myocardial ischemia.

The earliest electrocardiographic observations during anginal attacks were made by Bousfield (1918) and by Cowan and Ritchie (1922). The first electrocardiographic observations during angina pectoris, purposefully induced by exercise, were made by Feil and Siegel (1928). Depression of the RS-T segment was noted in the limb leads in three of four cases studied. Subsequent observations (1931) made by the same authors showed that other types of pain (labor, renal, and gallstone colic) caused no significant electrocardiographic changes in the limb leads. Numerous observers have shown that inversion of the T wave, typical changes of anterior or posterior myocardial infarction and temporary right or left bundle branch block may occur in addition to the depression of the RS-T segment. Missal (1938) and Puddu (1939) reported that precordial leads may show electrocardiographic changes in some cases in which there are no changes in the limb leads. Riseman, Waller, and Brown (1940) emphasized the influence of cold in angina pectoris and had patients exercise in a room at 45° to 50°F. Later it was found that merely having patients carry an ice cube in one hand also added the effect of peripheral vasoconstriction to the work of the heart.

Various methods of the electrocardiographic study of myocardial ischemia with exercise have been described.

Technic of the authors

A control electrocardiogram is first taken to determine whether or not there are abnormalities sufficiently diagnostic to confirm the presumptive diagnosis of coronary artery disease; that is, evidence of recent or old myocardial infarction. The record includes the limb leads, leads V_1, V_5 and V_6, and the three augmented extremity leads (AVR, AVL and AVF). If the record is not diagnostic, the patient then stands and lead IVR is taken. For this the right arm electrode is placed at the insertion of the right deltoid muscle and the left arm wire is attached to an electrode placed just lateral to the apex (Riseman). After the control record is taken, the patient is directed to take two steps up then down two steps (Master), turn and climb again. This exercise is repeated until pain or dyspnea develops. After completion of the test the limb leads and augmented leads should be recorded. The number of steps climbed depends on the degree of insufficiency of the coronary circulation and on the agility of the patient. Symptoms of insufficiency of the coronary circulation usually are produced in patients if they are subjected to a minimum of exercise after a meal (as suggested by Moia and Battle), if they exercise in a cool room or if an ice cube is grasped in the hand. In some patients the electrocardiographic changes develop maximally several minutes after the exercise and disappear slowly. If it is difficult for the patients to climb steps, then a test may be performed in the supine position. The patient attempts to sit up against the resistance of the physician's palm on the patient's chest.

Standard exercise test of Master

Master and his associates have devised a standard "two-step" exercise test of cardiac function determined by the response of pulse and blood pressure to exercise. Myocardial ischemia is graphically revealed by the electrocardiographic changes. The exercise (number of steps to be climbed) is standardized for age and weight since some electrocardiographic changes may occur if the effort is excessive. Tables giving the number of trips to be performed for different individuals have been published. In normal persons the blood pressure and pulse return to within ten points of resting levels in one and a half minutes. The following changes in the electrocardiogram after the exercise are considered by Master as abnormal: (1) a depression of the RS-T segment of more than 0.5 mm. in any lead and (2) a change from an upright T wave to an isoelectric or inverted T wave; or change in T wave in the opposite direction. The conclusions of Master

IMPORTANT ANNOUNCEMENT

This year, for the first time, the Annual Meeting of members of the Association will be held in conjunction with the Annual Scientific Session. It will be on the afternoon of June 28, 1946, in San Francisco. At this meeting Officers and Directors will be elected and reports given. The Chairman of the Nominating Committee is Dr. Paul D. White, Massachusetts General Hospital, Boston. He will gladly receive suggestions relating to nominations.

Headquarters for the Association will be the Hotel Fairmont, in which all or most of the meetings will be held on June 28 and 29. Members who wish to reserve rooms should write immediately to the San Francisco Tourist and Convention Bureau, Attention of Mrs. Hilton, specifying the Hotel desired and the probable duration of their stay. The Scientific Session will be on Saturday, June 29, and the Annual Dinner of the Association that evening.

are based on the performance of a test of slight exercise and interpretation of results are based on minimal electrocardiographic changes.

The electrocardiogram of normal controls after physical exercise

The electrocardiograms of normal controls show minor changes after moderate to severe exercise. The recognition of these minor changes is important, in order to avoid false electrocardiographic diagnosis. These changes are: (1) depression of RS-T segment less than 1 mm. in the limb leads and less than 2 mm. in the chest lead; (2) the T wave usually becomes less tall; (3) the T wave occasionally increases in height; (4) the T wave in lead III may change its sign.

Significant electrocardiographic changes in cases of arteriosclerotic heart disease

Significant electrocardiographic changes in these cases are as follows: (1) RS-T depression of more than 1.5 mm. in the limb leads and 2 mm. in lead IVR.; (2) typical picture of myocardial infarction; (3) bundle branch block and (4) change in sign of T wave except in lead III alone. These changes are all transient and usually disappear within five minutes after completion of the test, but may persist for a slightly longer period. These same changes may appear with dyspnea and in the absence of substernal pain. Occasionally the RS-T depression is greatest five minutes after the exercise has been completed. While the changes are usually seen in the chest lead (IVR), the signs of coronary insufficiency may be more marked in the limb leads. Suggestive or borderline changes should not be considered as confirming the diagnosis of coronary artery insufficiency. While the usual electrocardiographic change in coronary insufficiency is depression of the RS-T junction, occasionally the pattern resembles that seen in anterior or posterior myocardial infarction. We have had an opportunity at autopsy to examine the hearts of patients who had been tested. This examination has confirmed the predominance of the arteriosclerotic changes in the artery supply the predicted regions of ischemia as indicated by the electrocardiogram.

Effect of exercise on the electrocardiogram of normal people after digitalization

The effect of exercise on the electrocardiogram of normal individuals after digitalization was first noted by Zwillinger. He noted that after exercise the RS-T junction was occasionally depressed as in patients with coronary artery insufficiency. It follows that positive electrocardiographic findings after digitalization should not be regarded as diagnostic of coronary arteriosclerosis.

Discussion

Electrocardiographic observations during and after mild or severe exercise often provide objective confirmation of the diagnosis of arteriosclerotic heart disease with angina pectoris. Positive electrocardiographic findings are observed in 50 to 60 per cent of cases in which angina pectoris has been diagnosed clinically. A negative test should not rule out the diagnosis of coronary artery disease. Digitalis may cause a false positive result. Riseman, while confirming the electrocardiographic changes in attacks of induced angina pectoris, believes that changes after exercise appear to be of little practical value, for some subjects without heart disease may show changes similar to those which occur in some patients with angina pectoris, whereas other patients with angina may fail to develop appreciable electrocardiographic changes following the same amount of work. We are not in complete agreement with the conclusions of Riseman because of our interpretation of the significant abnormal changes.

The test is safe for patients who have not had recent myocardial infarction or myocardial failure. No patient who is not ambulatory and who has not been exercising moderately in his normal life should take the test. In the authors' personal experience with 500 tests, no serious or fatal results have occurred. Of course it is predictable that sudden death may occur during or soon after the exercise as sudden death not infrequently occurs in patients with arteriosclerotic heart disease under any conditions.

Simple stair climbing is an accustomed exercise of most patients and is the type of exercise that precipitates attacks of angina pectoris in many patients. Care should be taken not to make a positive diagnosis of arteriosclerotic heart disease on minimal electrocardiographic changes. In our experience this test has proved a valuable aid in the diagnosis of coronary arteriosclerosis with angina pectoris.

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THE ANOXEMIA TEST AS AN AID IN THE DIAGNOSIS OF CORONARY INSUFFICIENCY*

To appraise the clinical significance of pain in the chest and to locate its point of origin are not always easy tasks. Discomfort often is slight and is unrelated to effort or emotion. It may be felt only in the arms, the back or the epigastrium. The physical examination and electrocardiogram may fail to reveal evidence of cardiac disease. To determine whether the heart is at fault, because of an inadequate coronary blood flow, is a matter of first importance.

The anoxemia test furnishes an objective index of the functional efficiency of the coronary circulation. It is based on the observation that induced oxygen want produces changes in the form of the electrocardiogram which are more pronounced in patients with coronary insufficiency than in normal subjects. Criteria have been evolved which make possible the distinction between a positive and a negative response.

Apparatus

A tank containing a mixture of 10 per cent oxygen and 90 per cent nitrogen furnishes an unvarying concentration of oxygen in the inspired air. The gas flows through a humidifier into a rubber bag, which is kept full but not distended. Two flutter valves are incorporated into the system in such a way that rebreathing is avoided. A second tank, containing 100 per cent oxygen, is also in the circuit, so that, if desired, anoxemia can be quickly relieved by turning a needle valve.

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Procedure

The subject is allowed to rest quietly in bed for a period of at least thirty minutes. He is told that, if pain is experienced in the chest, arms or abdomen during the test, he should at once raise his hand. Electrocardiograms are taken with four leads; the standard leads and the precordial lead commonly designated IVF are used. The records are made just before the start of the test and at intervals of ten and twenty minutes thereafter. The standard period of inhalation is twenty minutes; but if pain is felt or there are signs of an undesirable reaction, an electrocardiogram is taken at once and 100 per cent oxygen is then administered for one or two minutes. If distress is severe, 100 per cent oxygen is given immediately, without waiting to take the electrocardiogram.

In each lead the deviation of the RS-T junction is measured in millimeters and the direction of the T wave is noted.

Criteria of a positive test

The result is positive when any one of the following is found: 1. The arithmetic sum of the RS-T deviations in all four leads (I, II, III and IVF) is greater by 3 mm. or more, than in the control. 2. There is partial or complete reversal of the direction of the T wave in lead I, accompanied by an RS-T deviation of 1 mm. or more in this lead. 3. There is complete reversal of the direction of the T wave in lead IVF, regardless of any associated RS-T deviation in this lead.

Precautions to be observed

The control record should be developed and read before the test is begun in order to be certain that a recent cardiac infarct is not present. If there is doubt on this point, it is best not to proceed. In addition, the test should not be performed under the following circumstances: (1) if it has been done on the patient within the past twenty-four hours; (2) if congestive failure is present; (3) if cardiac infarction is known to have occurred within the preceding four months.

Unpleasant effects

In the course of a series of studies of induced anoxemia, the test was given to patients with cardiac disease of different types and varying degrees of severity. Vasovagal attacks were occasionally observed. These consisted of slowing of the heart rate, fall in blood pressure, coldness of the skin, pallor and sweating. Mild convulsive seizures, dyspnea and hyperventilation were also noted in a few cases. Barnes and his associates have recorded ventricular premature contractions, nodal rhythm and brief cardiac standstill during the anoxic period.

Acute pulmonary edema occurred in three of our cases, with prompt recovery following the hypodermic injection of morphine, inhalation of oxygen and rest overnight. In three elderly patients with sclerotic cerebral vessels, there was mental confusion, lasting less than fifteen minutes.

Deaths

In two of our cases, the physician in charge failed to read the control electrocardiogram before making the test. As a result, one of the patients died suddenly during the procedure. Both the electrocardiogram and the autopsy showed fresh infarction of the myocardium. In the second case, ventricular tachycardia appeared after seven minutes of anoxemia. The arrhythmia persisted in spite of intramuscular injections of quinidine and oxygen therapy in a tent. Death occurred four hours later. In this instance, likewise, the control record clearly indicated a recent infarct. Autopsy was not done.

Results

In the Department of Cardiology at the Presbyterian Hospital, the test has been performed several thousand times. A detailed account of its use in 289 cases at the Mayo Clinic has been published recently by Pruitt, Burchell and Barnes. It has been employed by the Medical Departments of the Army and Navy. At the New York Hospital, Stewart has had a wide and untroubled experience with it. In Nylin's clinic, in Stockholm, more than 1000 tests have been made. These examples are cited to indicate that data are accumulating.

In any large series of cases, the percentage of positive tests will depend on the nature of the material studied. Instead of giving figures, it seems more profitable to make certain general statements which appear justified by the facts so far available:

1. A positive reaction may be regarded as a sign of coronary insufficiency.

2. A negative reaction does not exclude disease of the coronary arteries. As is the case in any functional test, there must be a significant diminution in reserve before this can be demonstrated objectively. It cannot be too strongly emphasized that no clinical importance should be ascribed to a negative result.

3. In our experience, the occurrence of pain during a test which is electrocardiographically negative, is worthy of attention. If discomfort is similar in character to the original complaint, there is evience that anoxia is capable of reproducing it. Follow-up of this group of patients has shown that a large percentage later developed unmistakable symptoms and signs of coronary heart disease. In many of them the anoxemia test subsequently became electrocardiographically positive.

In the opinion of Barnes and his associates, pain induced by anoxemia is of no greater diagnostic value than the patient's description of his symptoms. This viewpoint is not supported by our studies. Obviously, the observer must make the distinction between pain of cardiac origin and the minor discomfort of an apprehensive subject. Usually this is not difficult. No significance should be attributed to the complaint of pain when payment for disability is involved.

The result of a test during which pain occurs but electrocardiographic changes are absent, must be reported as negative. Patients in this category should be followed with special care and managed conservatively.

4. The test does not yield a quantitative expression of the degree of coronary insufficiency. But in a given patient, there may be variations which parallel the clinical course. With improvement associated with the development of a collateral circulation, a positive test often becomes negative. Conversely, reduction in coronary flow may change a negative into a positive response.

5. It is not possible to predict, on the basis of the result, the likelihood of future coronary occlusion. The test affords an index, within undefined limits, of the adequacy of the coronary circulation at a particular time. When positive, it indicates a diminished coronary reserve. It yields no information concerning the nature or extent of the pathologic lesions in the heart.

Comment

If the precautions outlined are observed, the anoxemia test is a simple, safe procedure. With the proper selection of cases, even the mildly unpleasant reactions can be largely avoided. It has been shown to be of clinical usefulness in the differential diagnosis of coronary insufficiency. It has been employed, also, to study the effects, in man, of various drugs and of reflex factors on the coronary circulation. It does not require active co-operation on the part of the patient and anoxemia can be abolished promptly at any time by administering 100 per cent oxygen.

For routine clinical purposes, the anoxemia test should be restricted to cases in which the diagnosis of coronary insufficiency is in doubt. Only a positive result is significant.

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